Fig. 1 - Aircraft Flight Process

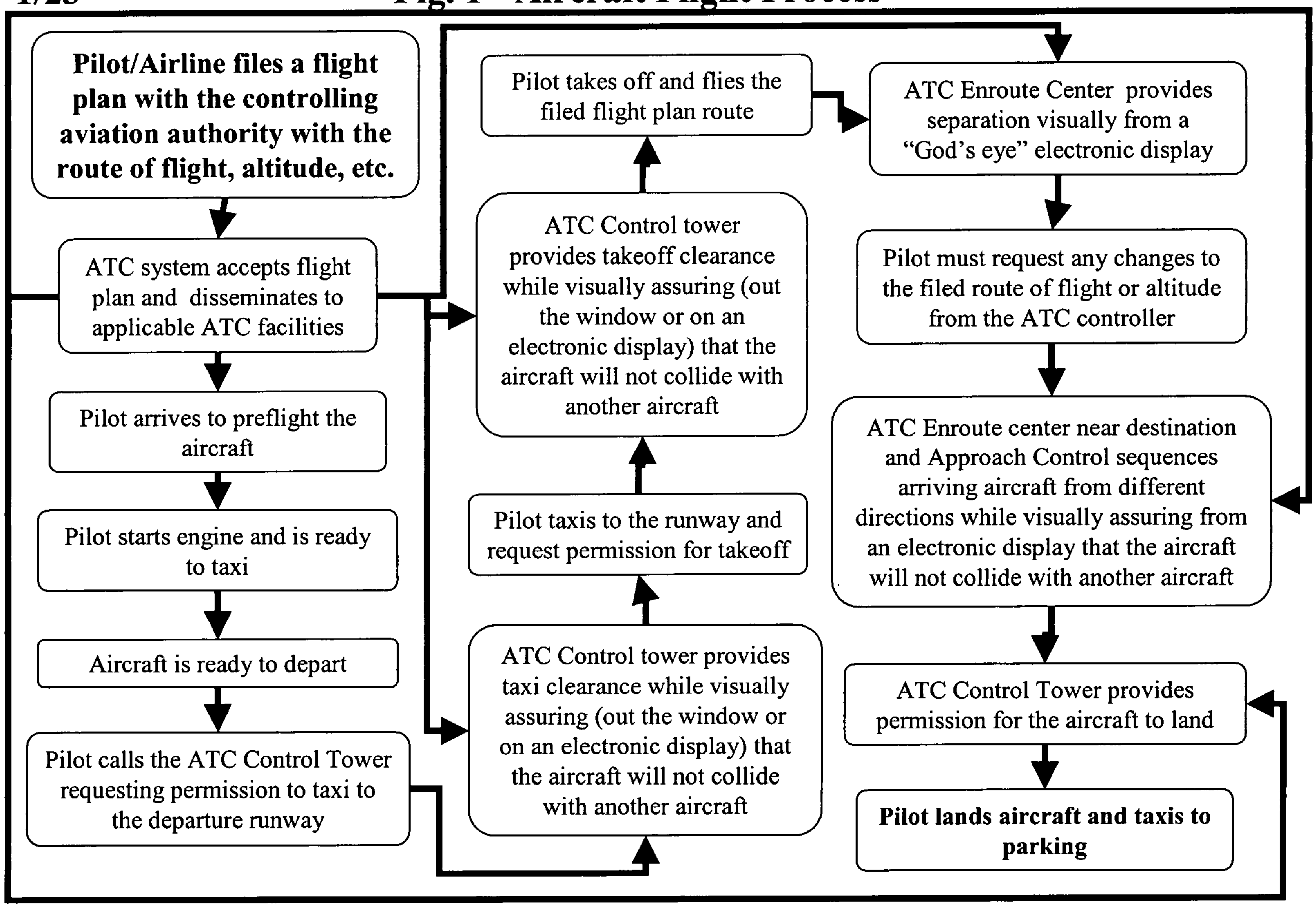


Fig. 2- Airport Arrival/Departure Flow

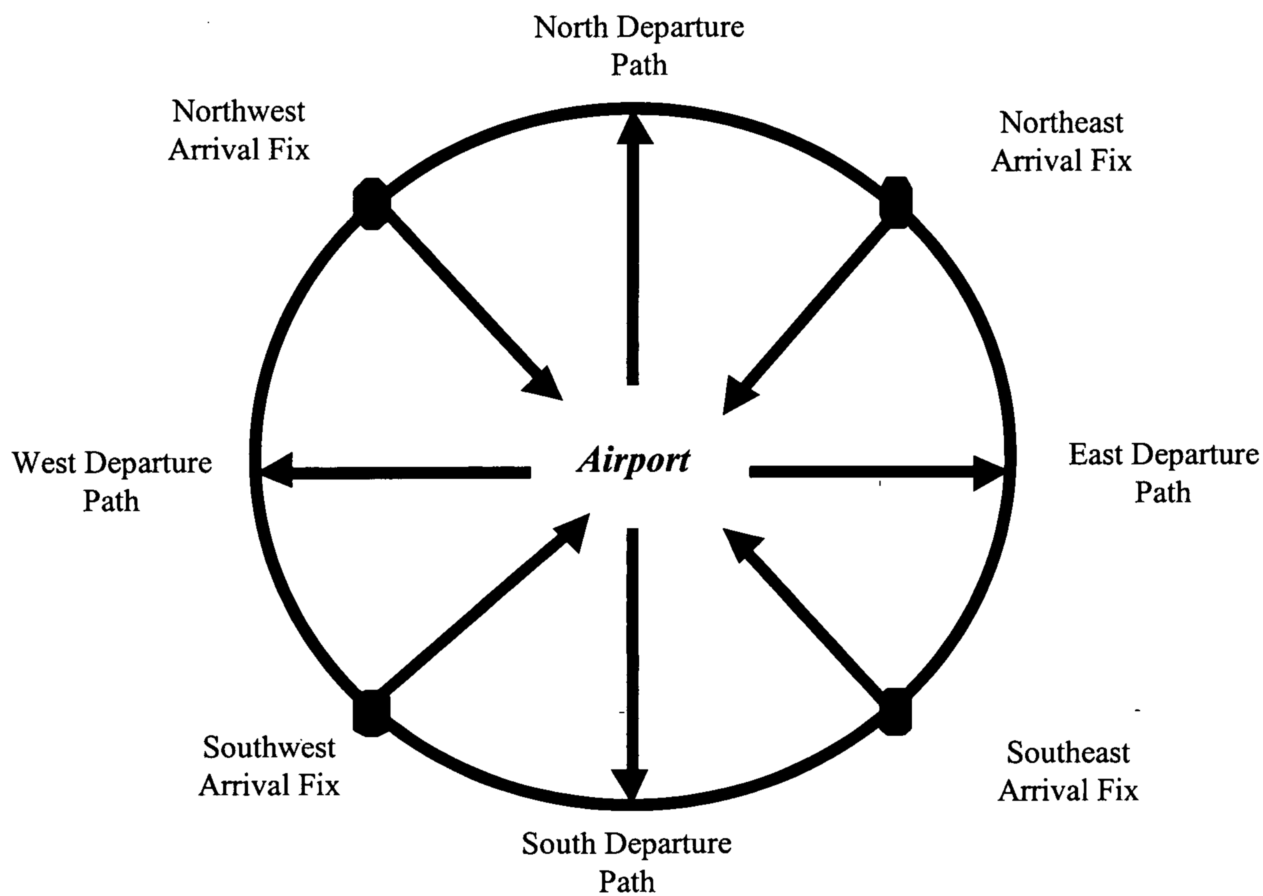


Fig. 3 - DFW CTAS Data,
2200 TO 2230 CMT Arrivals - 11/6/98

1. AAL458	SJC	18R	2201
2. EGF026	MEM	17L	2201
3. AAL1707	TPA	17C	2201
4. EGF202	SHV	17L	2202
5. EGF784	ACT	13R	2202
6. TWA453	STL	18R	2202
7. EGF736	TUL	17L	2203
8. AAL1498	SNA	18R	2203
9. AAL2038	IAH	17C	2203
10.AAL79	EGK	17C	2204
11.EGF650	LIT	17L	2204
12.AWE544	PHX	18R	2205
13.EGF854	TYR	17L	2206
14.KHA200	FTW	13R	2206
15.DAL237	ATL	18R	2207
16.EGF094	GGG	17L	2207
17.AAL1779	LIT	17C	2207
18.EGF128	TXK	17C	2208

19.EGF718	MAF	13R	2208
20.AAL656	ABQ	18R	2209
21.EGF114	LCH	17L	2209
22.AAL2161	EWR	17C	2209
23.EGF621	HOU	17L	2210
24.EGF704	XNA	17C	2210
25.AAL1188	ONT	13R	2210
26.AAL50	DEN	18R	2211
27.AAL1714	LAS	13R	2212
28.AAL839	MSY	17C	2213
29.AAL1412	ELP	18R	2214
30.AAL1720	OKC	13R	2214
31.AAL1306	SLC	13R	2215
32.AAL2233	ORD	17C	2216
33.COA186	IAH	18R	2217
34.AAL1404	COS	17C	2217
35.AAL742	MCI	13R	2218

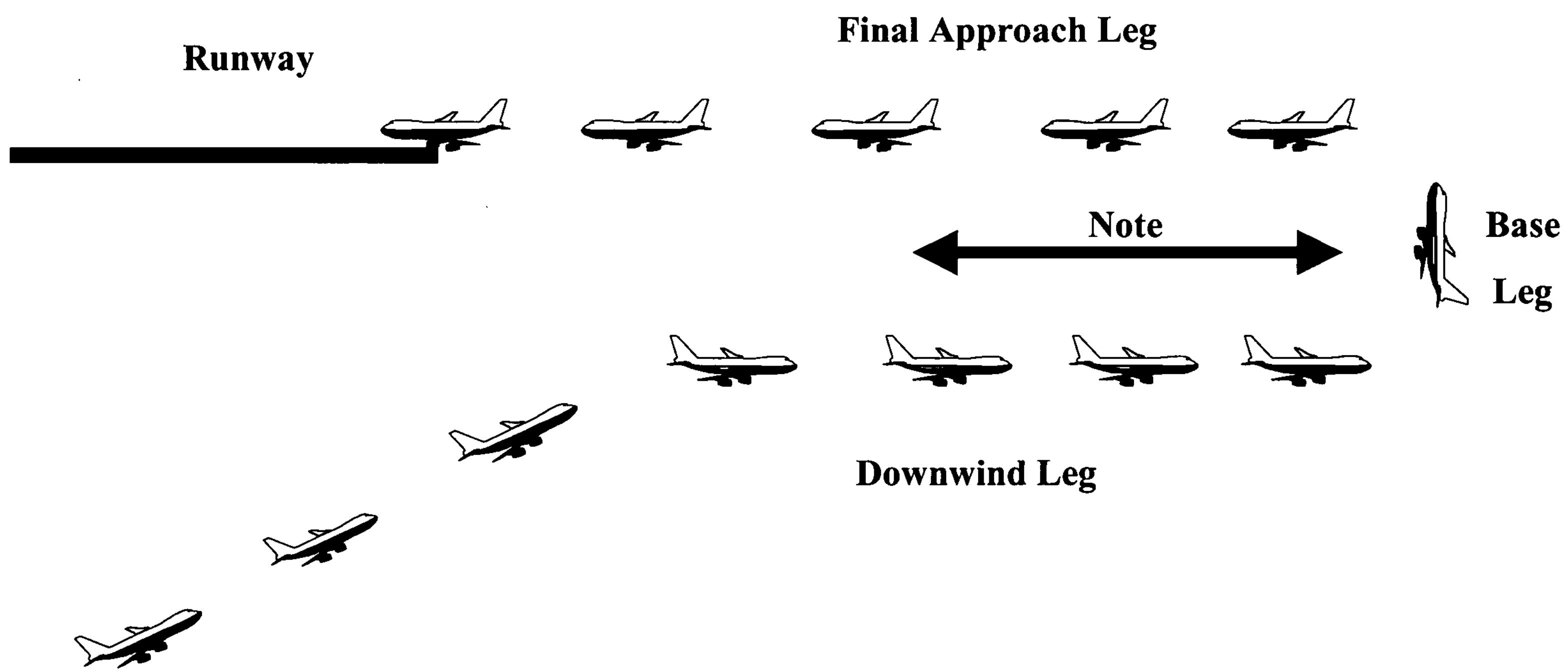
36.USA777	PIT	18R	2218
37.AAL1016	SAN	17C	2219
38.AAL1280	LGB	18R	2219
39.AAL1884	SAT	17C	2220
40.AAL794	SEA	13R	2221
41.AMT255	MDW	18R	2221
42.AAL48	PHX	13R	2222
43.AAL564	ICT	17C	2222
44.AAL496	TUS	18R	2223
45.AAL9649	MCO	17C	2223
46.AAL1552	SFO	18R	2226
47.AAL1890	LAX	17C	2226
48.UAL478	SFO	18R	2228
49.UAL1055	ORD	18R	2229
50.AAL1978	AUS	17C	2230

Fig. 4 - December 2000 DOT Data

DECEMBER 2000 AIR TRAVEL CONSUMER REPORT
TABLE 3. PERCENTAGE OF ALL CARRIERS' REPORTED FLIGHT OPERATIONS ARRIVING ON TIME
BY AIRPORT AND TIME OF DAY (REPORTABLE AIRPORTS ONLY)

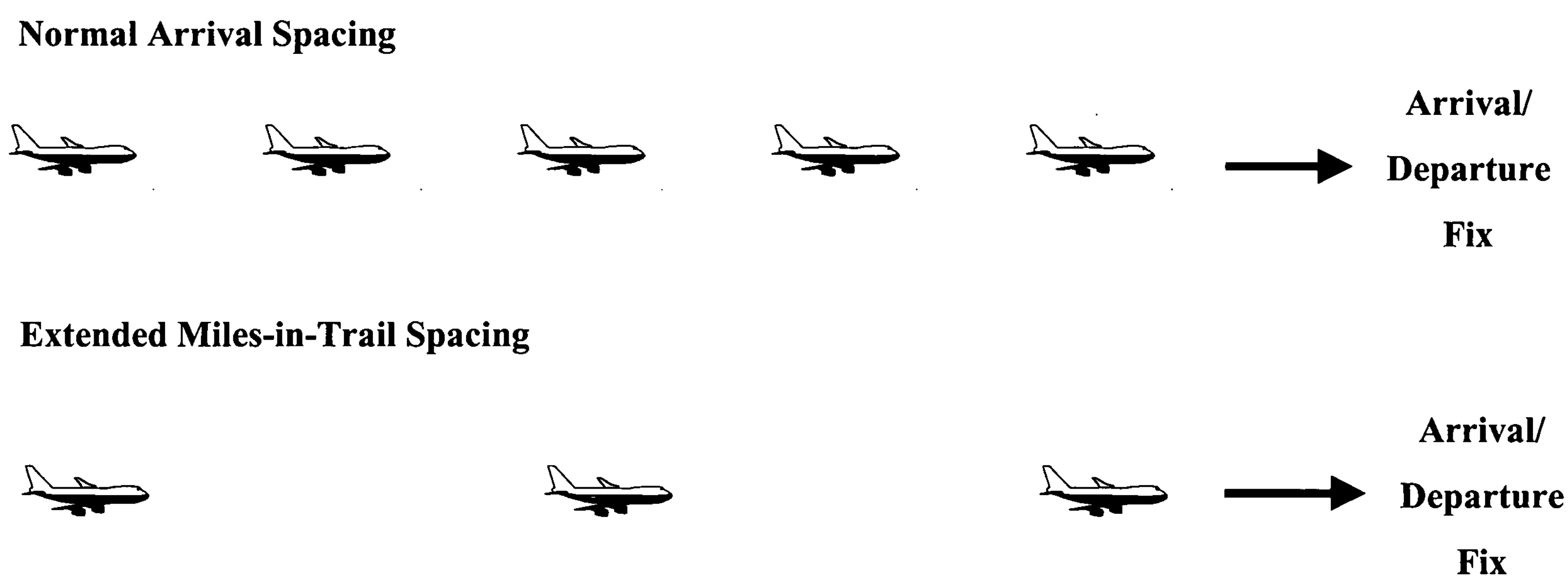
ARRIVAL AIRPORT SCHEDULED ARRIVAL TIME	ATL	BOS	BWI	CLT	CVG	DCA	DEN	DFW	DTW	EWR	IAH	JFK	LAS
600 - 659 AM	80.4	72.7	71.0	91.3	66.7	50.0	72.4	75.1	63.7	71.0	90.4	72.8	90.7
700 - 759 AM	71.5	71.1	84.0	81.5	68.6	70.8	71.9	80.5	68.6	72.0	84.6	65.6	92.3
800 - 859 AM	62.7	68.3	84.6	71.7	75.7	81.5	74.5	68.3	64.1	73.3	80.2	80.6	76.7
1000 - 1059 AM	60.4	67.9	75.5	66.1	73.8	68.6	65.1	72.1	67.0	74.0	77.4	78.0	61.3
1100 - 1159 AM	61.3	70.0	78.7	75.1	59.7	71.8	72.7	70.5	63.7	72.7	70.6	J/	68.1
1200 - 1259 PM	60.3	68.9	79.2	65.2	61.3	68.0	62.7	71.9	66.7	67.8	82.5	J/	64.0
100 - 159 PM	52.9	70.2	68.5	75.0	73.3	71.4	62.8	74.3	59.6	66.8	75.2	72.9	63.9
200 - 259 PM	56.6	67.6	71.2	70.5	71.0	71.7	68.4	63.6	55.4	67.3	74.4	67.6	65.1
300 - 359 PM	55.5	62.1	69.4	67.1	65.2	76.3	67.5	70.9	59.1	67.6	72.2	76.6	65.7
400 - 459 PM	54.0	65.9	68.2	64.7	58.0	69.6	58.3	68.4	60.3	66.2	74.6	69.9	61.6
500 - 559 PM	50.6	60.4	68.1	71.7	60.5	63.0	62.7	57.4	56.0	60.3	69.1	71.6	55.9
600 - 659 PM	52.8	60.4	65.4	63.5	60.2	65.9	53.6	62.6	54.0	61.1	69.1	59.2	63.6
700 - 759 PM	44.7	64.7	59.6	66.5	59.9	67.4	54.3	66.2	56.6	63.1	74.0	58.2	57.2
800 - 859 PM	49.3	60.0	58.5	58.1	56.7	68.9	61.6	55.5	49.7	65.5	67.1	59.6	57.8
900 - 959 PM	48.7	59.6	65.4	71.3	61.9	60.0	61.9	62.9	60.3	66.3	64.7	68.9	60.1
1000 - 1059 PM	53.8	63.0	63.4	50.0	38.3	68.1	59.5	57.1	53.9	60.8	54.9	64.9	60.9
1100 - 559 AM	57.7	62.1	63.7	65.7	55.7	55.4	59.9	65.5	56.9	70.7	62.8	68.1	61.9
TOTAL by Airport	56.9	65.0	69.8	70.1	64.5	69.1	64.1	67.1	59.9	67.0	73.7	68.2	64.6

Fig. 5 - The Runway Arrival Trombone



Note - Additional aircraft are warehoused by extending the distance from the base leg to the runway (i.e., extending the trombone), which lengthens the downwind and final approach segments of the approach allowing space for the extra aircraft.

Fig. 6- Miles-In-Trail



The additional miles-in-trail spacing is done by laterally extending the route or turning the aircraft.

Fig. 7 - Airborne Holding

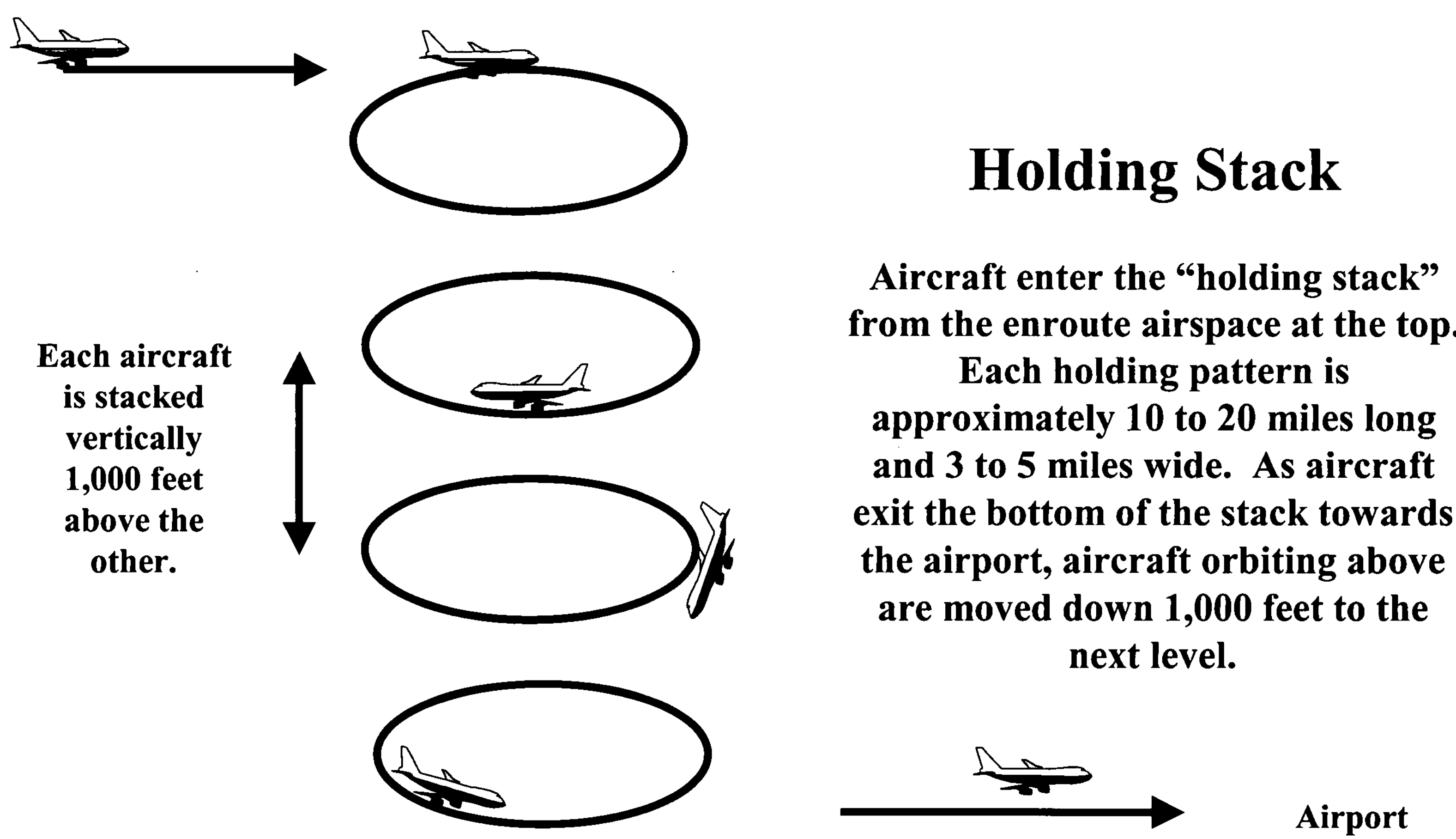


Fig. 8 - Methods of the Present Invention

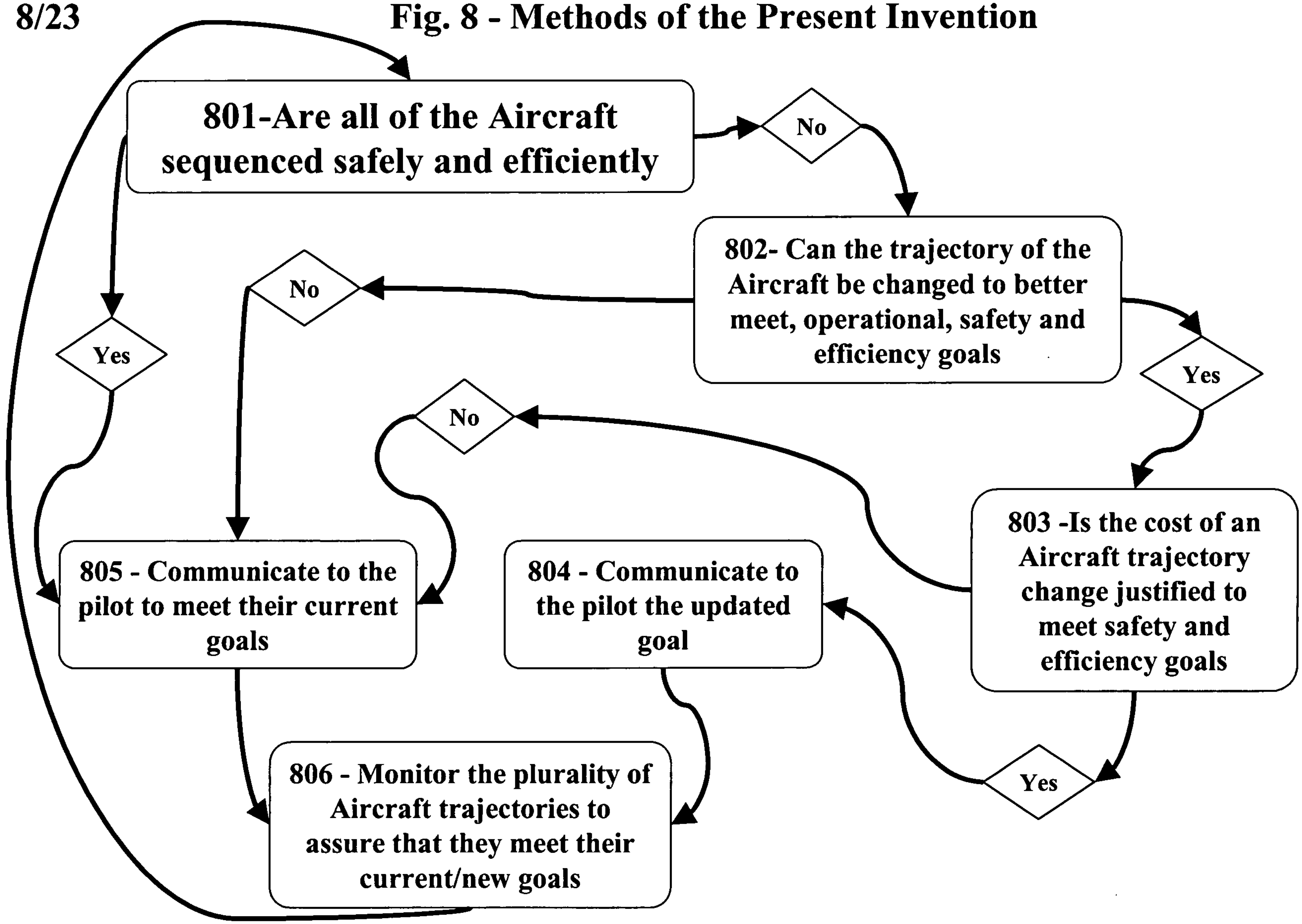


Fig 9a - Decision/Command Matrix

Critical Factors:

1. What is the optimum airport arrival time for each aircraft as determined by the airline/user/pilot?
2. What can the individual airlines do to meet the needs of all of the aircraft approaching the airport?
3. Is the airspace infrastructure (runways, airspace, arrival fix) capable of meeting the aircraft needs taking into account available assets and the needs of all of the other aircraft?
4. What time are the control actions taken? [Note: the future trajectory prediction of all of the assets is an important aspect of this decision]
5. Decisions 1 and 2 are made by the user and passed to the Aviation Authority (if this is the operator) for integration to the present invention. Absence any information to from the airline/user/pilot, the present invention works towards safety, operational and efficiency goals.

Fig. 9b - Decision/Command Matrix

Decision 1 - Intra-Aircraft Decisions

Focus - Aircraft and User Needs and Wants

What does the individual aircraft need and/or want?

Arrival at airport at OAG Scheduled Arrival Time
Evaluate future trajectories for needs (Look Ahead)
Enough airport Time to:
- Get Passengers off/on
- Get Baggage off/on
- Get Cargo off/on
- Complete Aircraft Servicing (lavs, food, etc.)
- Complete required maintenance items
- Depart on time for next segment

Enough connection time for passengers

Maintenance Actions
- Scheduled maintenance
- Unscheduled repairs
- Deicing
- Known repairs

Shorter route
Comfortable ride
Use Minimum Fuel
A gate upon arrival
Crew (Pilots and Flight Attendants)

Key Questions

What services does aircraft need? Regular or special?
What time does aircraft want to arrive in a perfect world?

Aircraft Characteristics

Safe Speed Range
Fuel Burn Model (fuel available to make desired change)
Wind Model
Altitude Capability (aircraft weight)

Enroute Weather Model
Enroute Turbulence Model
Aircraft position data
Fuel Burn Model (minimum fuel usage)

Fig. 9c - Decision/Command Matrix

Decision 2 - Intra-Airline Decisions

Focus - Airline Capabilities to meet needs of all aircraft

Can the airline meet the aircraft's needs?

- Gate Availability
- Jetway or Stair Availability
- Baggage Crew Availability
- Fueling Availability
- Flow of Passenger Connecting Flights
- Mechanic Availability
- Dynamic Gate Management
- Asset Trajectory Matching
- Cleaning Crew Availability
- Agent Availability
- Galley Loading/Unloading
- Parts Availability

Key Questions

- What is the airline's ability to meet the needs of all aircraft?
- Will airline service capability delay aircraft?

Airline Data

- Airport data
- Fuel truck data
- Passenger data/model
- Mechanic data
- Crew data
- Customer Service Agent data
- Galley data
- Aircraft parts data

Fig. 9d - Decision/Command Matrix

Decision 3 - Aviation Authority Decisions

Focus - Infrastructure Capabilities to meet needs of all aircraft

Can the infrastructure meet the aircraft's needs?

Airspace Availability
Arrival Fix Availability
Weather
Airline/pilot requirements (Decision 1 and 2 data if available)
Runway Availability
Infrastructure Trajectory Matching
Demand

Key Questions

What is the aviation authority's ability to meet needs of all aircraft?
Will infrastructure constraints delay aircraft?

Infrastructure Data

Runway Acceptance Rate
Weather
Cornerpost Acceptance Rate
Equipment Status

Fig. 9e - Decision/Command Matrix

Control Action 1 - Airline/Aviation Authority

Focus - How and When to Make Control Action Happen

Control Actions

Transmit fix crossing time to aircraft

Monitor actions to assure aircraft response meets the new assigned goals

Key Questions

What time should control action take place?

How should pilot be notified?

Fig. 10 - Data Sets

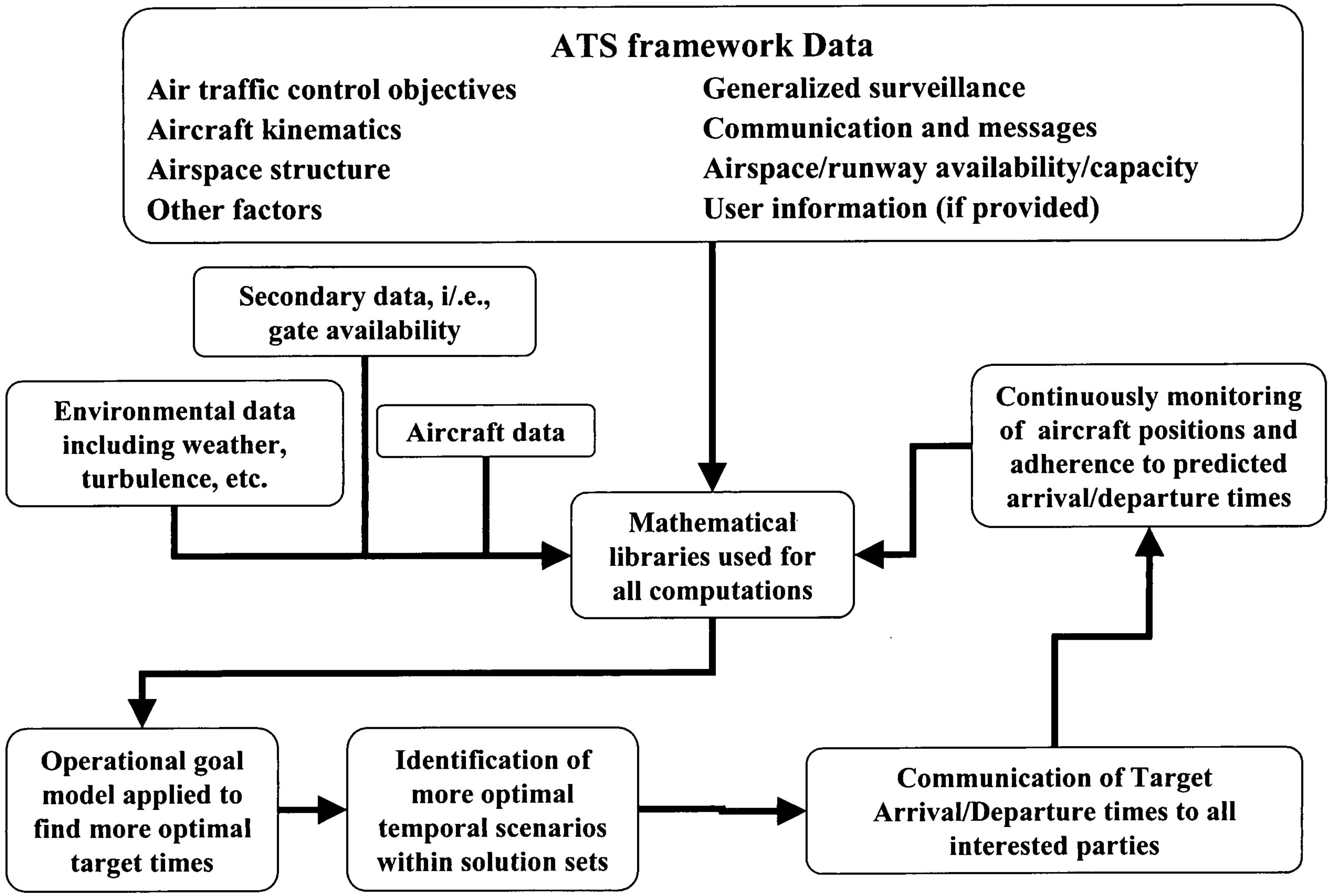


Fig. 11a - Sample of the Method's Processing Sequence

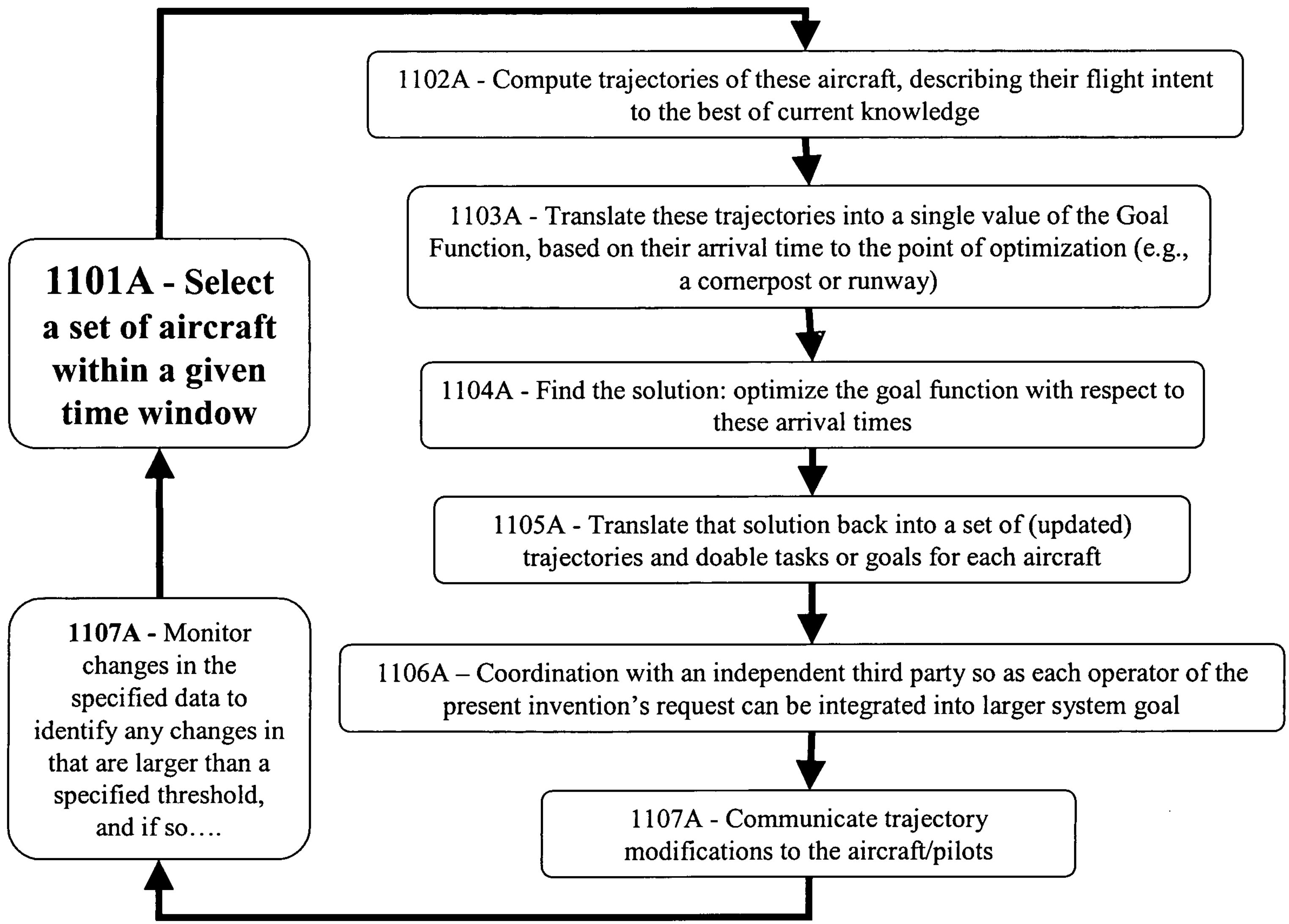


Fig. 11b - Sample of the Method's Processing Sequence

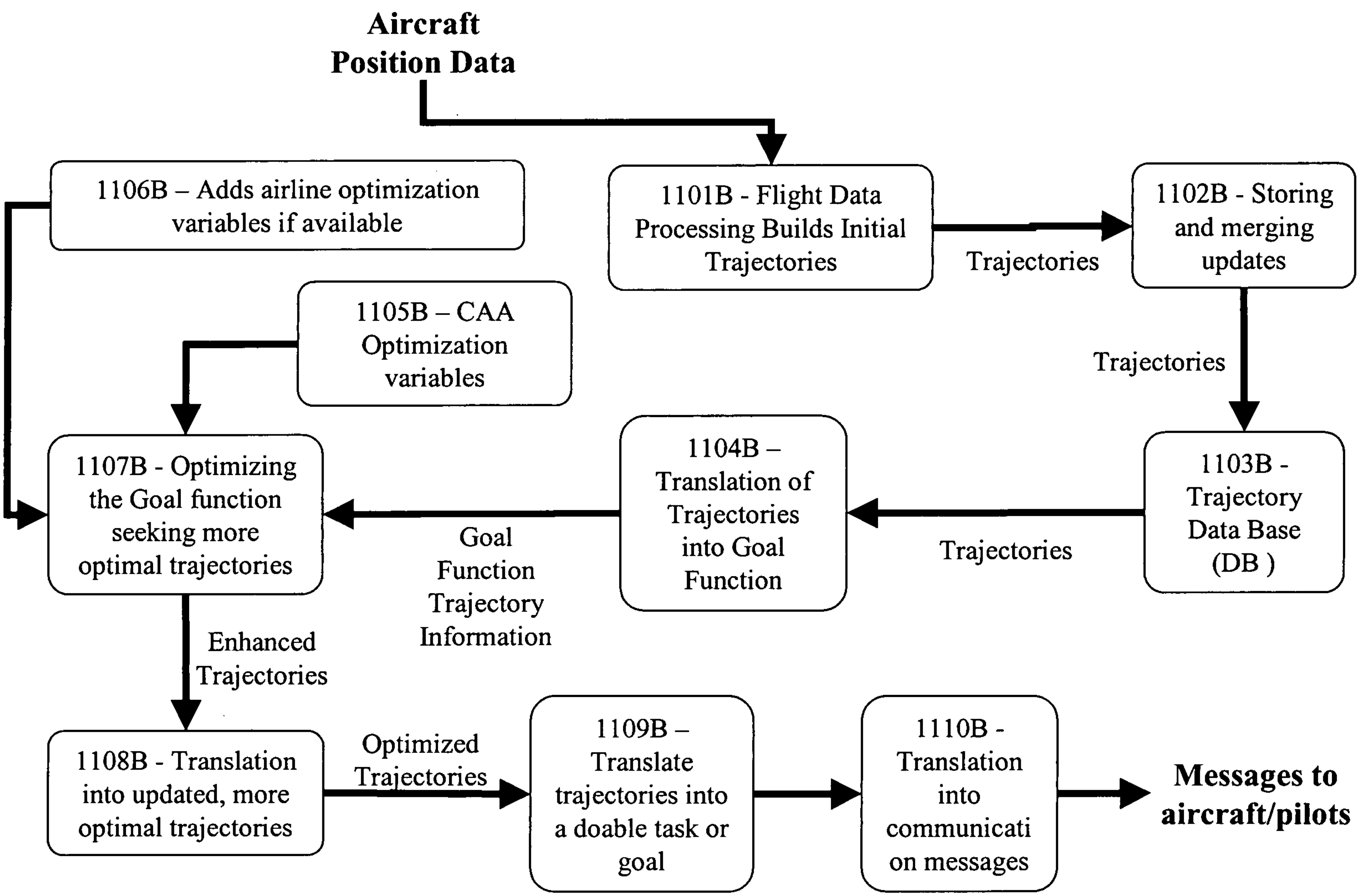


Fig. 12 - Random versus Time Sequenced Cornerpost Arrival Flow For the Same Set of Aircraft

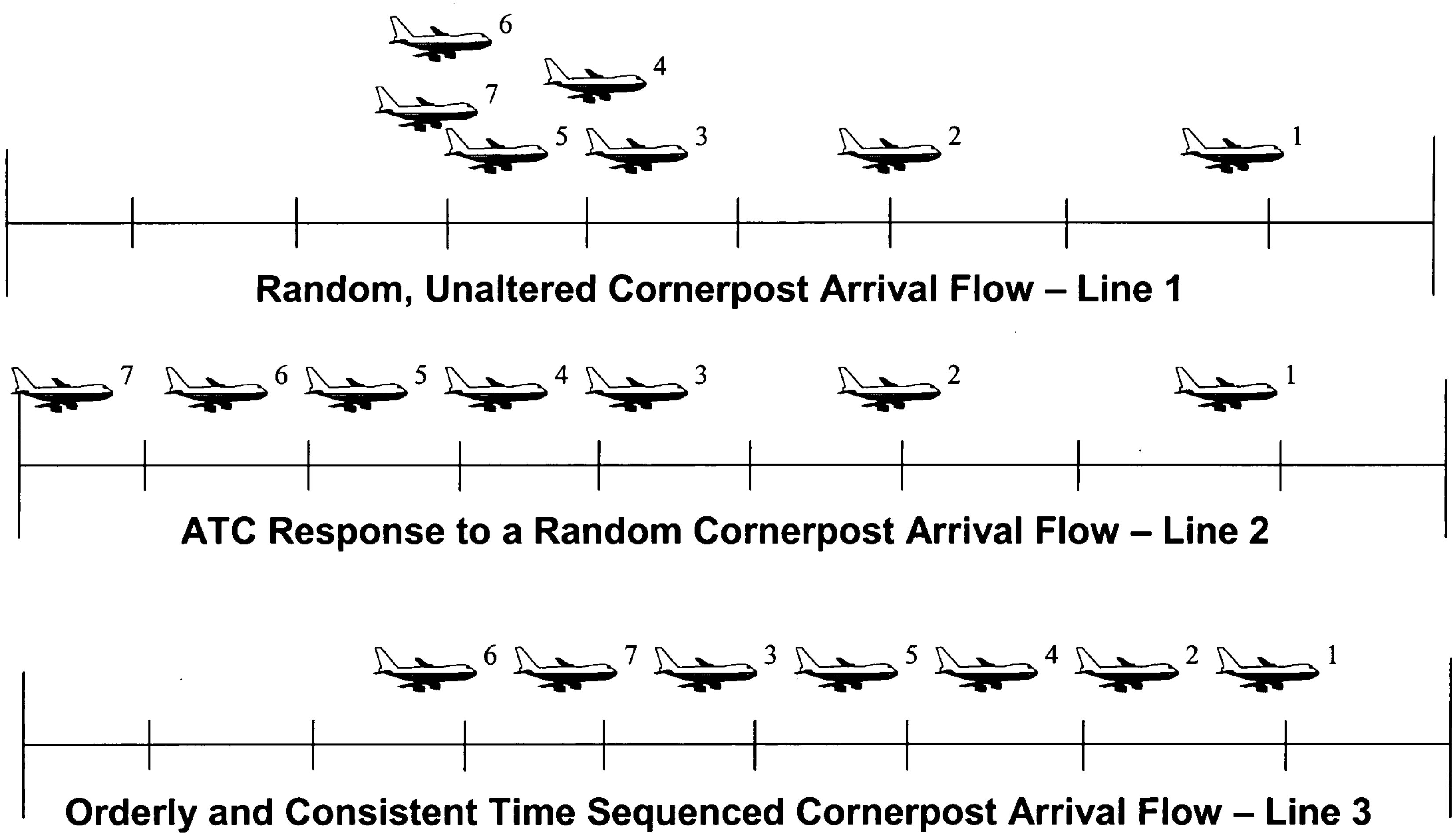


Fig. 13 - Typical Hub Arrival Schedules versus Capacity Shown In 15 Minute Blocks

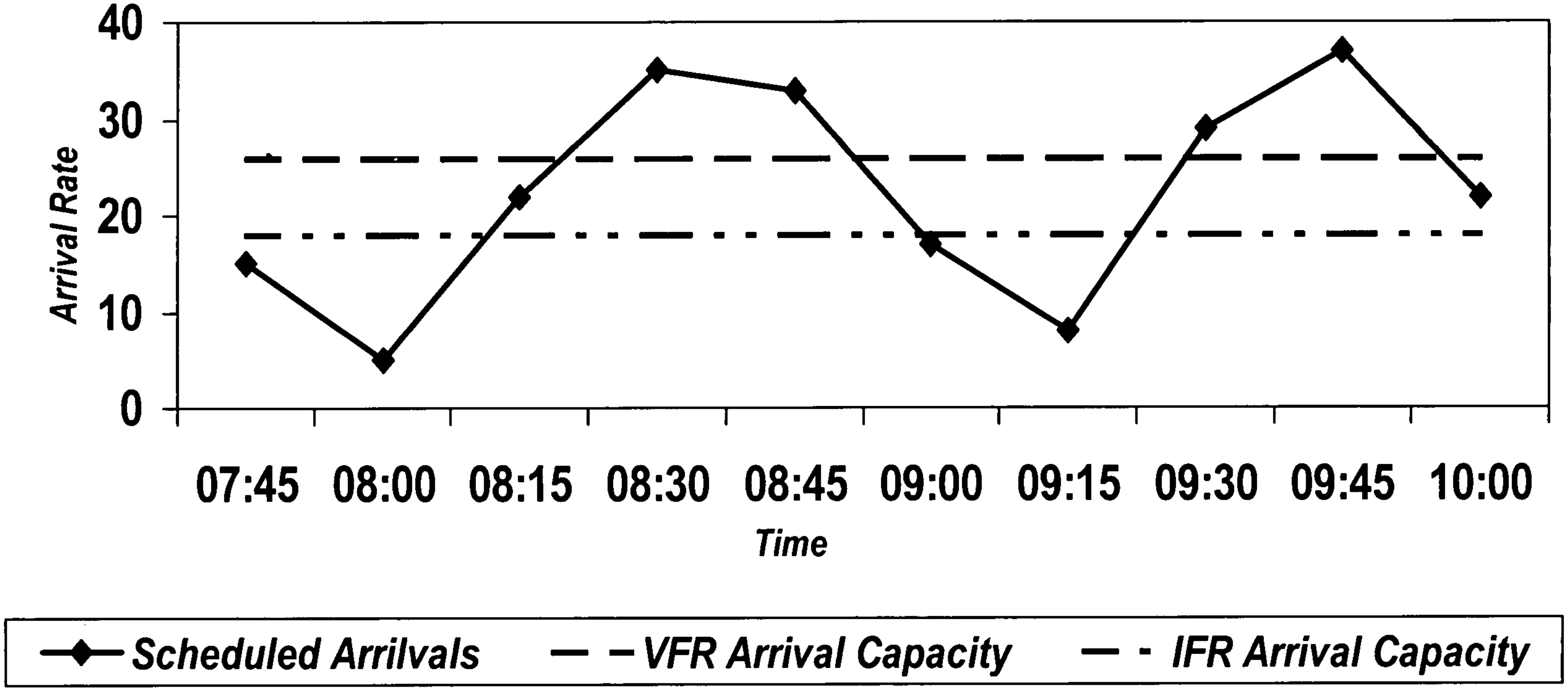


Fig. 14 - Single-aircraft Goal Function component for two aircraft (example)

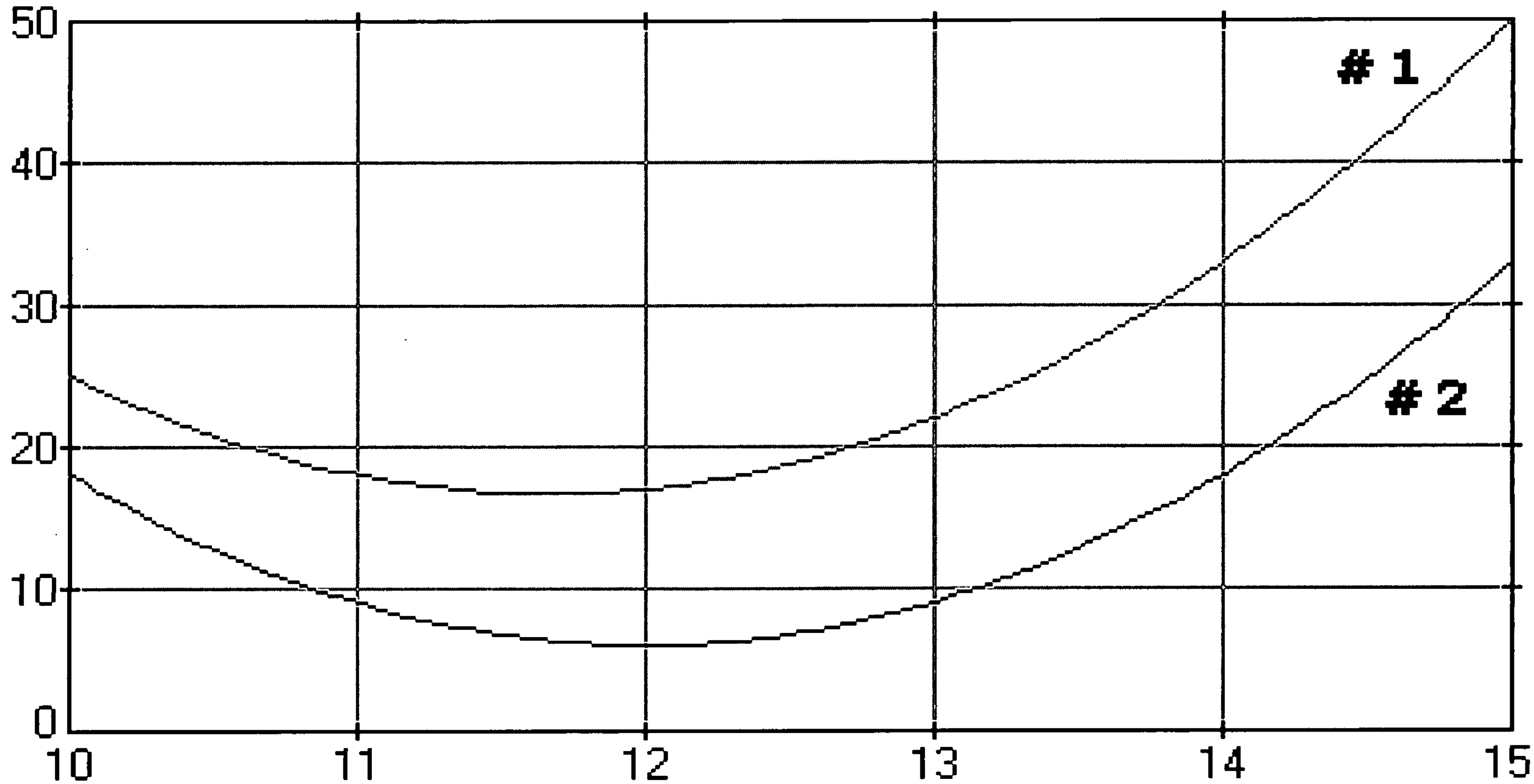


Fig. 15 - Total Goal Function for a system of two aircraft (example)

	$t_2 = 10$	$t_2 = 11$	$t_2 = 12$	$t_2 = 13$	$t_2 = 14$	$t_2 = 15$
$t_1 = 10$	1043	34	31	34	43	58
$t_1 = 11$	36	1027	$\boxed{24}$	27	36	51
$t_1 = 12$	35	26	1023	26	35	50
$t_1 = 13$	40	31	28	1031	40	55
$t_1 = 14$	51	42	39	42	1051	66
$t_1 = 15$	68	59	56	59	68	1083

Fig. 16 – Sample Process to Coordinate Arrival Fix Times by Multiple System Operators.

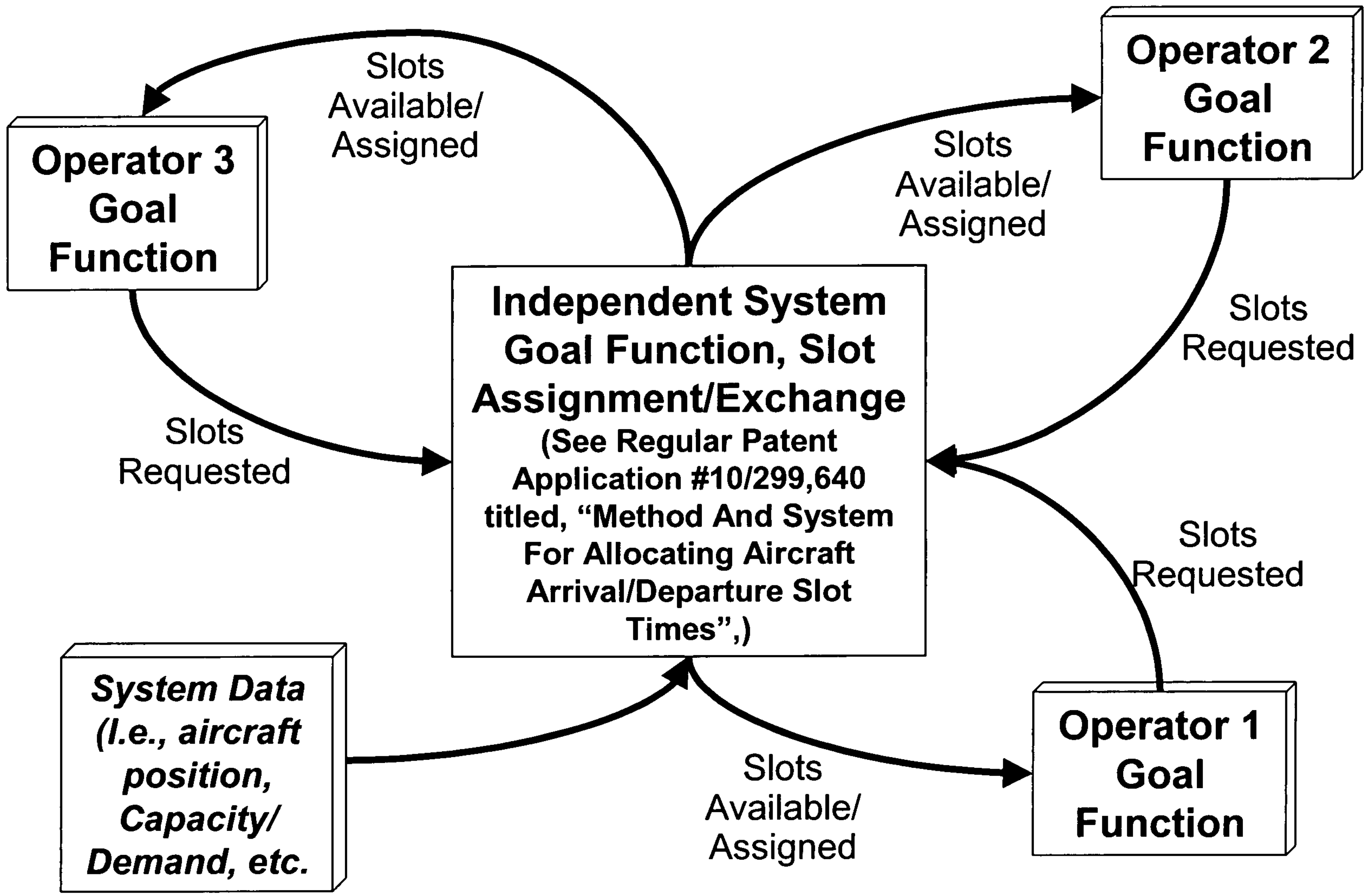


Fig. 17 – Effects of Variance

.. effects of variance get worse as demand nears the capacity o the system ..

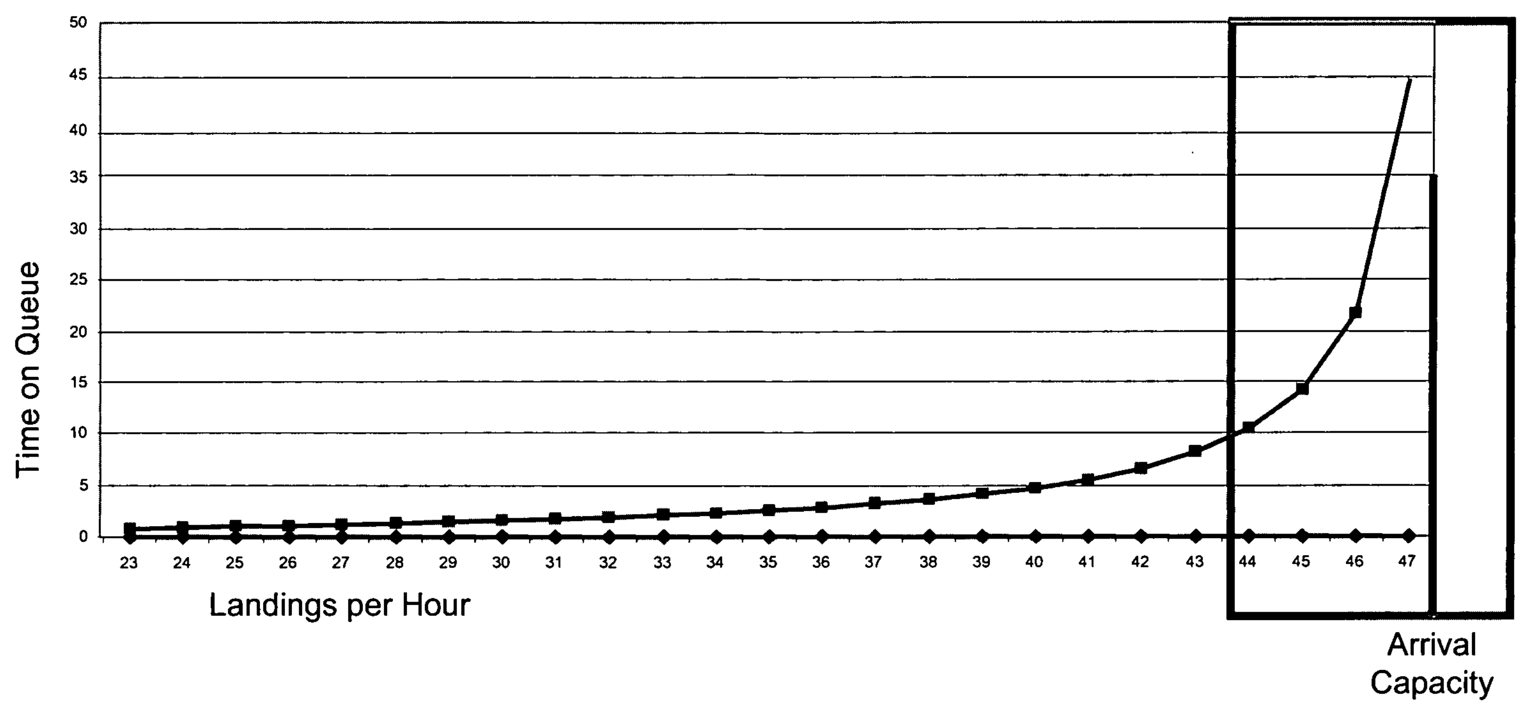
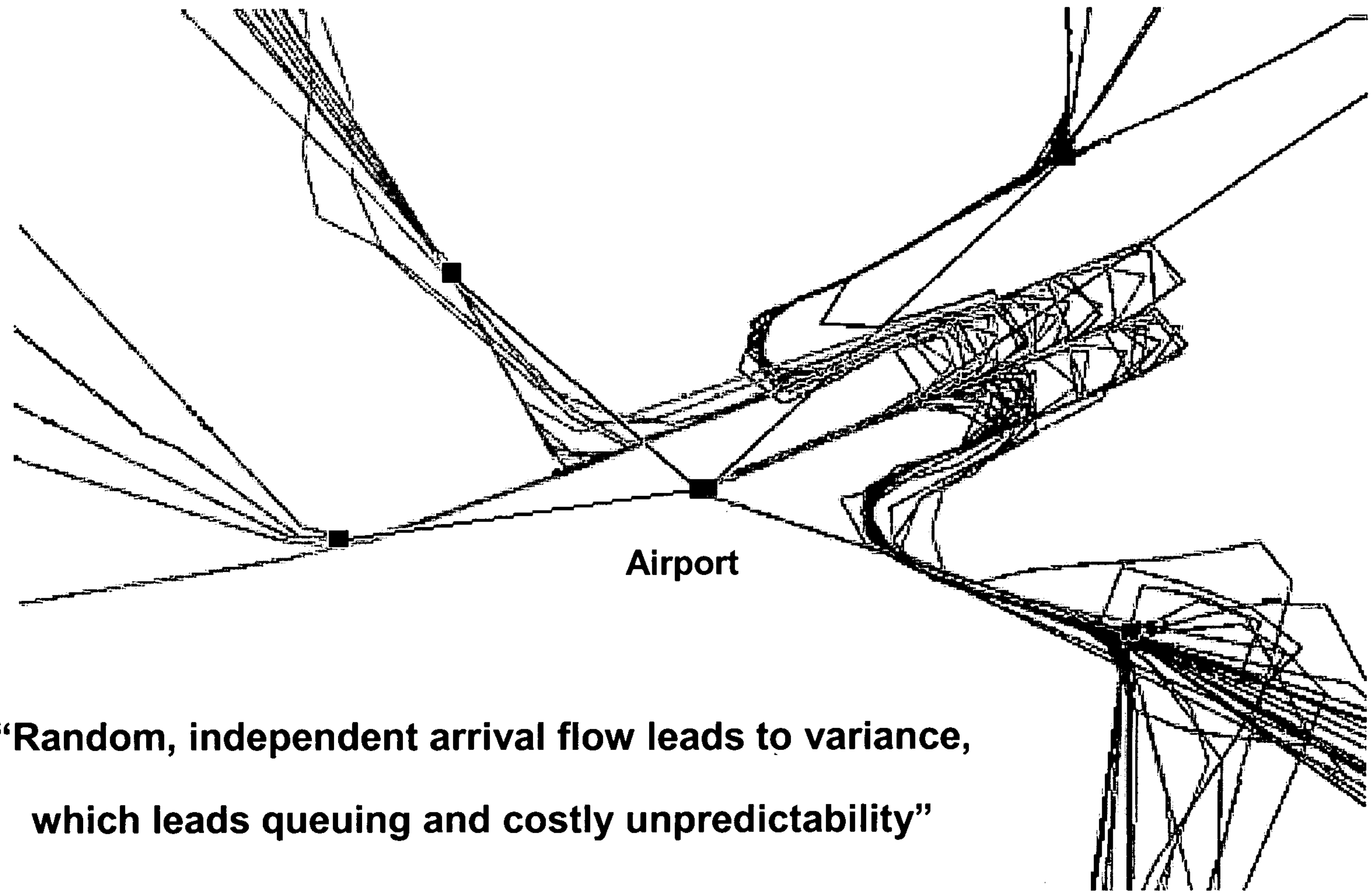


Fig. 18 – Arrival Path Variance of a Typical Aircraft Arrival Flow to an Airport



"Random, independent arrival flow leads to variance, which leads queuing and costly unpredictability"